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14. ABSTRACT
The CTBTO (Comprehensive Test Ban Treaty Organization) Hydroacoustic sites have been operational for (depending on location) up to 10+ years. The sites are under the National control of the countries Australia, Canada, Chile, France, Mexico, Portugal, UK of Great Britain & Northern Ireland and the United States. The data is a continuous stream of ambient noise, from each sensor-----the interest is in long term ambient noise recordings; study of specific source functions and their temporal behavior. The frequency range of the system is limited to approximately 1 to 100 Hertz, with the consequent restriction of potential noise sources at Wake Island, Ascension Island and Diego Garcia.

15. SUBJECT TERMS
Hydroacoustic, ambient noise, waterborne signals

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Ambient Noise Analysis from Selected CTBTO (Comprehensive Test Ban Treaty Organization) Sites

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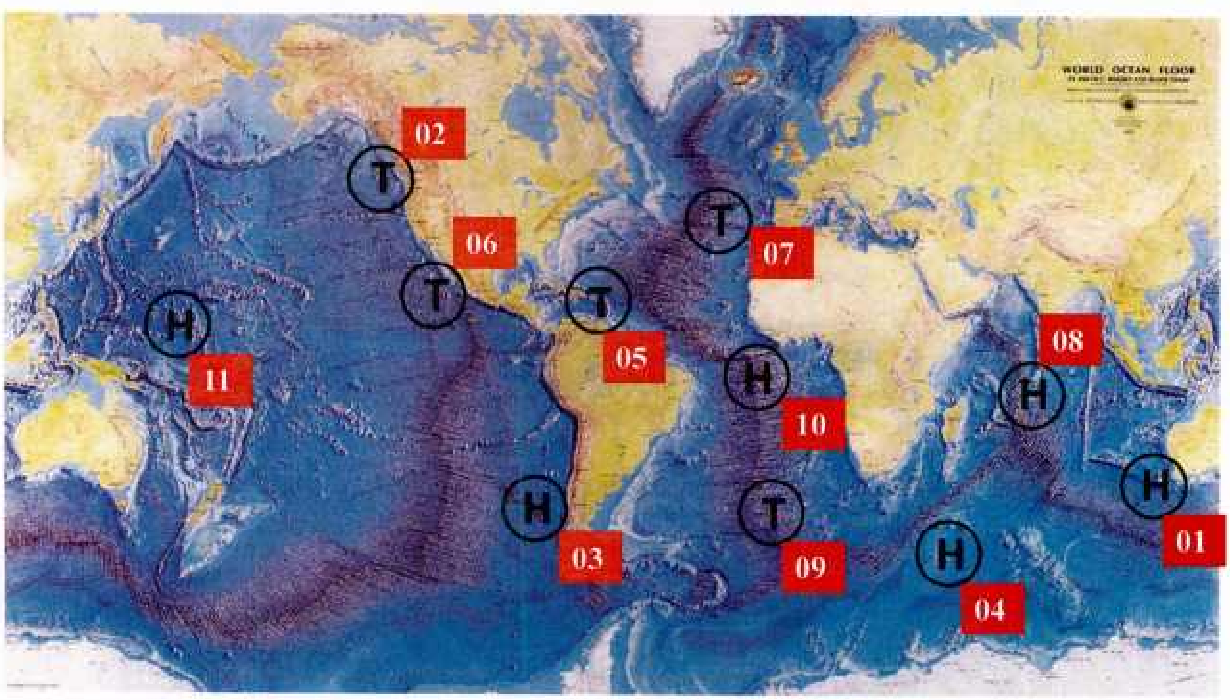
Background

The CTBTO (Comprehensive Test Ban Treaty Organization) Hydroacoustic sites have been operational for (depending on location) more than a decade. Their locations are shown on the accompanying Figure 1. They are of two types; first are "normal" hydrophones, moored in the water column at sound channel axis depth; second are seismic "T-phase" sensors, located on a "seamount-like" island, either mounted on land or in the water as OBSs. In all cases a "site" is at least two sets of three individual sensors, located in a manner to take advantage of the location geography for shielding, either for N-S or E-W (or other directions) discrimination. The ambient noise data, from .002 to 125 Hz, is communicated via satellite for 24/7 monitoring to Vienna, Austria. The sites are under the National control of the countries in the list of Table I, and via AFTAC/US NDC (Air Force Tactical Applications Center/ US National Data Center), at a minimum, US site data is available, with the potential of all sites, should they be necessary. What is the data? A continuous stream of calibrated ambient noise, from each sensor-----the assumption is that there will be some kind of a built in time delay, but the interest is not real time oriented.

Figure 1

Ocean Bathymetry
CTBTO Hydroacoustic Sites



(H) - **Hydro Acoustic Stations**

(T) - **T - Phase Stations**

Table I

Hydroacoustic

Treaty Number	Station Name	Country	Status
HA01	Cape Leeuwin, WA	Australia	Certified
HA02	Queen Charlotte Islands, B.C.	Canada	Certified
HA03	Juan Fernandez Island	Chile	Certified
HA04	Crozet Islands	France	Under Construction
HA05	Guadeloupe	France	Certified
HA06	Socorro Island	Mexico	Certified
HA07	Flores	Portugal	Certified
HA08	BIOT/Chagos Archipelago	United Kingdom of Great Britain and Northern Ireland	Certified
HA09	Tristan da Cunha	United Kingdom of Great Britain and Northern Ireland	Certified
HA10	Ascension	United States of America	Certified
HA11	Wake Island	United States of America	Certified

Statement of Work

Program of Study

The research is graduate student "centric", with the request limited to support of one student for two years (the normal time to obtain an MS in the PSU Graduate Program in Acoustics) with one month support per year for the principal investigator for student advising and data analysis. Because the research was extended for Doctoral studies, a follow on proposal is in preparation.

Research and Technology Objectives

The data available from the CTBTO Hydroacoustic sites has the potential to be valuable for a number of research thrusts. Common to all, effort was setting up the process of data "flow" into ARL from the National Data Center noted above, establishing the procedures for storage, cataloging and analysis of the ambient noise files, which was accomplished early in the program and has been successfully used by multiple investigators.

Statistical details of ambient noise are a critical and fundamental parameter set, when describing/using ambient noise. The potential for exploiting that level of information for source location, behavior, identification, etc for use in passive and noise limited active acoustic systems has focused on Gaussian assumptions and correlation methods; consequently not isolating specific sources and propagation conditions, and represents a research opportunity. An example of potential analysis would be to organize by source function (distant shipping, for example) and examine by season to determine if the statistical behavior varies with that parameter, which would provide a measure of impact on the statistics of ambient noise by propagation variation.

The use of CTBTO resources provides the potential of good (seismic) source localization, together with the waterborne signals for specific events. Definitive source positioning, together with waterborne event arrival times will allow reconstruction of paths that in turn, will provide model inputs for the energy transition from solid earth into the sound channel.

Impact

Development of the capability of spatially (or more specifically, geographically) filtering distant shipping to develop a global scale time-space "picture" of ocean basin or regional activity, and the combination this "filtered" data with economic, military activity and other "geo-political" drivers that influence/control shipping leads to the development of "metrics" that can be used to predict distant shipping based ambient background. This modeling capability would be used to provide "Acoustic Environment" maps to deployment planning and strategy studies and be coupled to "in situ" measurements for operational use.
While the Wenz curves are well documented and understood to be long time averages of ambient noise, the statistics, given the diversity of sources and propagation conditions, have unique time and spatial behaviors that can be exploited, if they are properly described and catalogued. As above, when you isolate the causal events to specific locations and times, this information would also provide operational data to aid proper interpretation of acoustic sensor data.

An unanswered geophysical question is the mechanism(s) by which low frequency energy gets into the water column from the constant seismic activity below the seafloor. The levels observed (high) do not equate to the analysis to date, which is driven by source angles of entry and consequent transition into the sound channel, continental slope conversions, etc. The use of CTBTO resources provides the potential of excellent (seismic) source localization, together with the waterborne signals for specific events. Definitive source positioning, together with waterborne event arrival times will allow reconstruction of paths that in turn, will provide model inputs for the energy transition from solid earth into the sound channel.

Related Projects

Liaison with CTBTO personnel has been successful and will continue on an "as needed" basis. If progress dictates, potential international collaboration may be warranted, but funded independently via other sources. In addition, Jennifer Miksis-Olds, an ARL colleague, has independently, via an ONR TYP, been working with Division 322, Marine Mammals & Biology Program, Code 32 (James Eckman, Program Manager) for a more focused Ocean Biology study using the same data sets as above.

Progress/Results

- Close to 30 years of accumulated CTBTO data has been downloaded and either being used or available for use at ARL/PSU. (with continued downloading on a monthly basis as more recent data is released)

- Increase in noise level with time at Wake Island is consistent with other studies (Fig 2)
- Power spectral density comparison between the three oceans investigated indicates the Indian Ocean has a significant difference from Atlantic and Pacific (Fig 2)
- The opportunity to compare data collected near Wake Island in the early 90's led to an initial study of the sound field behavior in the 1-10 Hz range and the results are summarized below.

  Spectral slope between 1-5 Hz can be explained by surface wave dynamics (Fig 3)

  Average Spectral Slope: $-18.7 \pm 2.5 \ \frac{dB}{Octave}$ (Fig 4)

  Similarity in spectral slopes suggests that this value may be a global deep-water constant, as proposed by McCreery et al. (Ref 4)

- Further Confirmation of the wind dependence behavior of ambient noise is the infrasonic band 1-5 Hz. (Fig 5 and Ref 11)
- Development of a frequency correlation field method to isolate ambient noise sources in frequency space. (See Figs 6 & 7 and Ref 12)

Figure 2

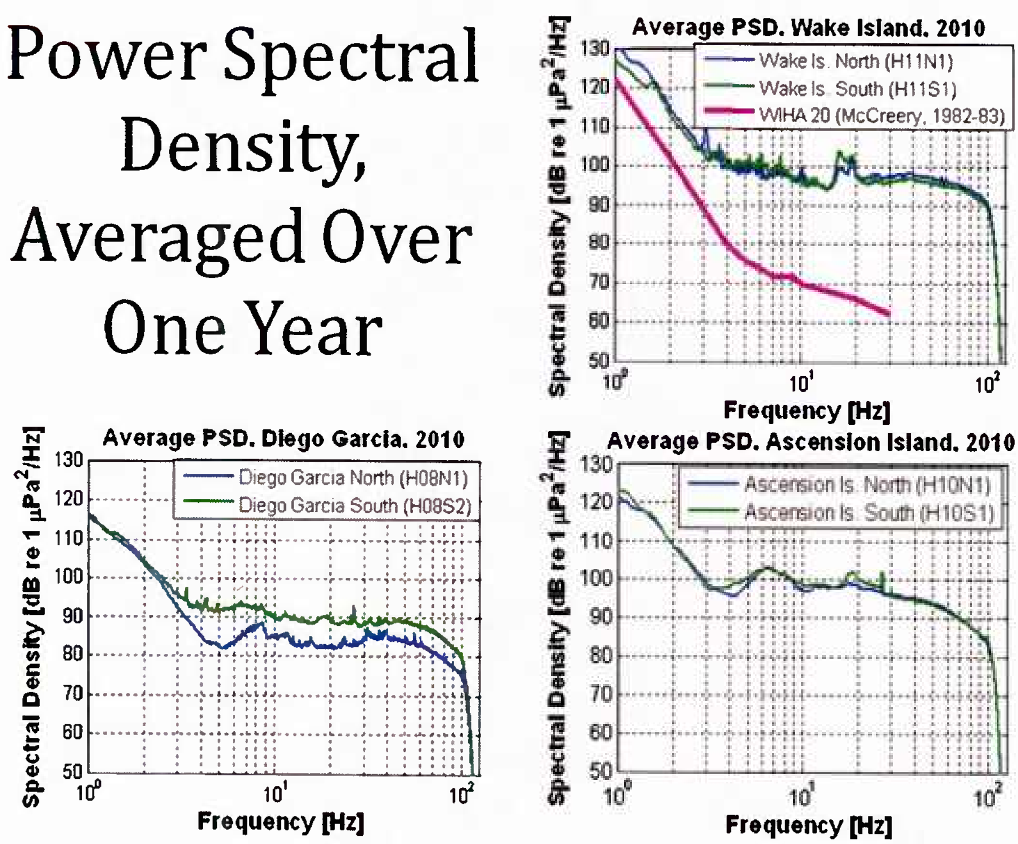
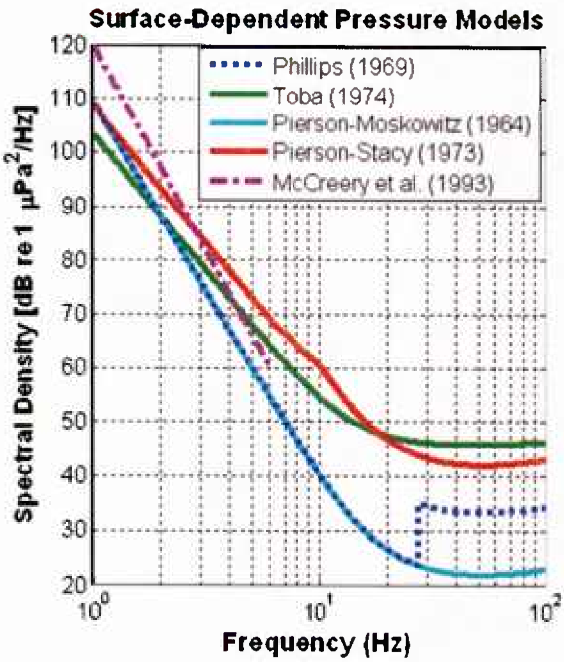


Figure 3

Ambient Noise Models



- Experimental:
  - McCreery et al.
    - $S_p \propto f^{-7.6}$ $\left(-23\frac{dB}{Octave}\right)$
- Theoretical:
  - Phillips & Pierson-Moskowitz
    - $S_p \propto f^{-7}$ $\left(-21\frac{dB}{Octave}\right)$
  - Toba & Pierson-Stacy
    - $S_p \propto f^{-5}$ $\left(-15\frac{dB}{Octave}\right)$

Figure 4

Wake Island

- North:

  $$-20.9\frac{dB}{Octave}$$

  $(1.4 - 2.8\ Hz)$

  - Best Fit: Phillips
- South:

  $$-21.8\frac{dB}{Octave}$$

  (1.6 – 2.8 Hz)

  - Best Fit: Phillips

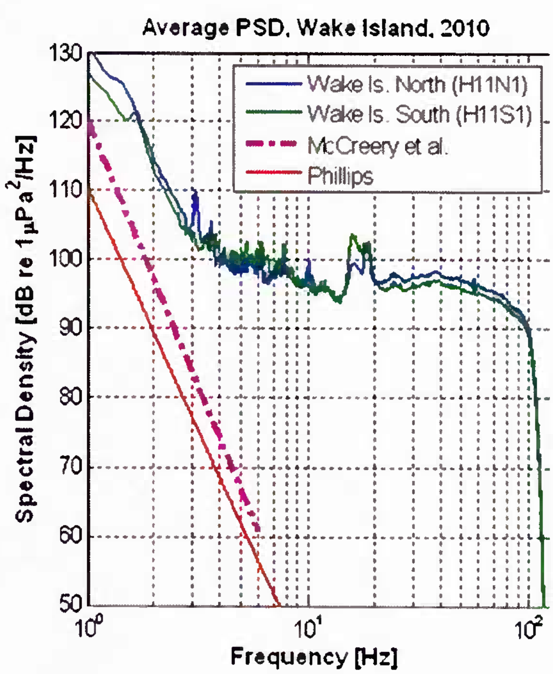


Figure 5

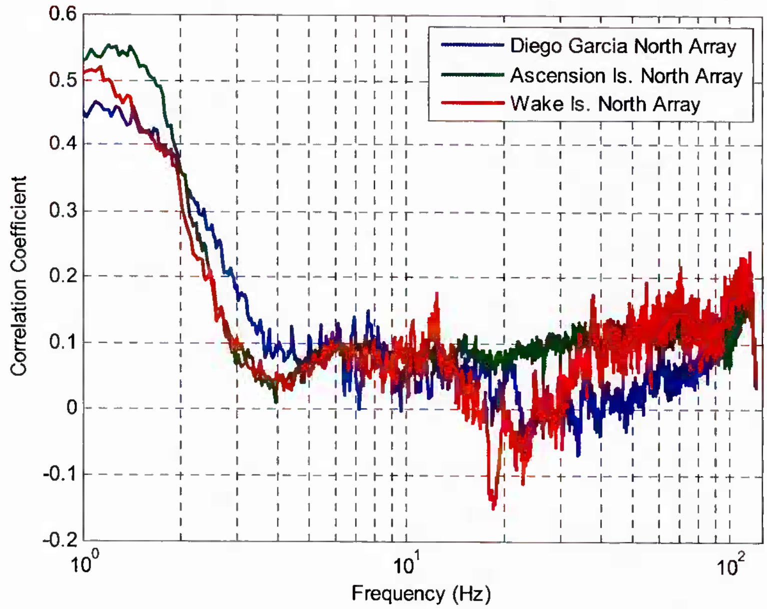


FIGURE 5. Correlation coefficients between spectral densities in individual 1/30 Hz frequency bands and the local wind speed, calculated using noise data from the northern array at each of the three CTBTO hydrophone stations, recorded between July 1 and September 30, 2010.

Figure 6

Ascension Island

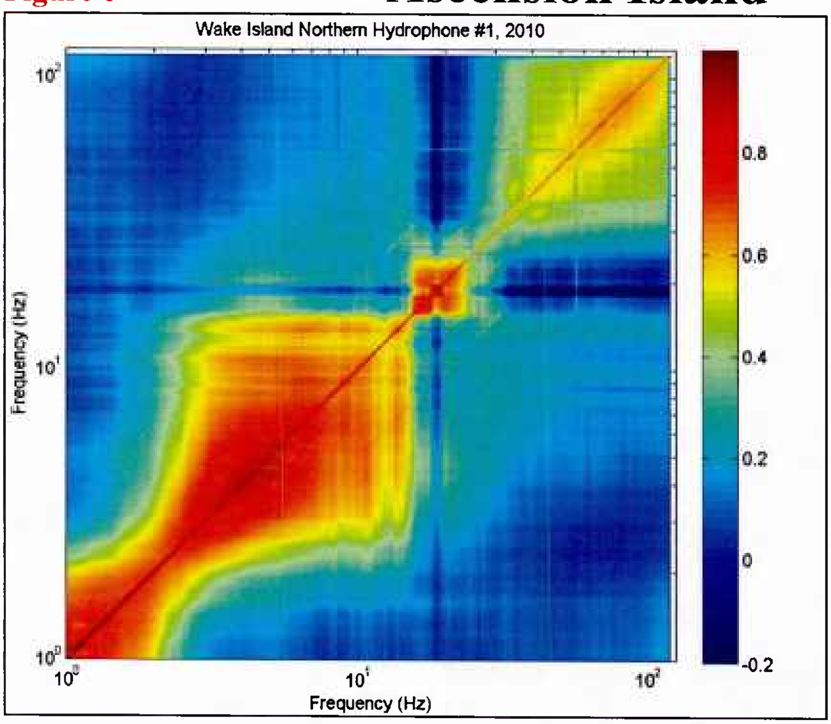


Figure 7

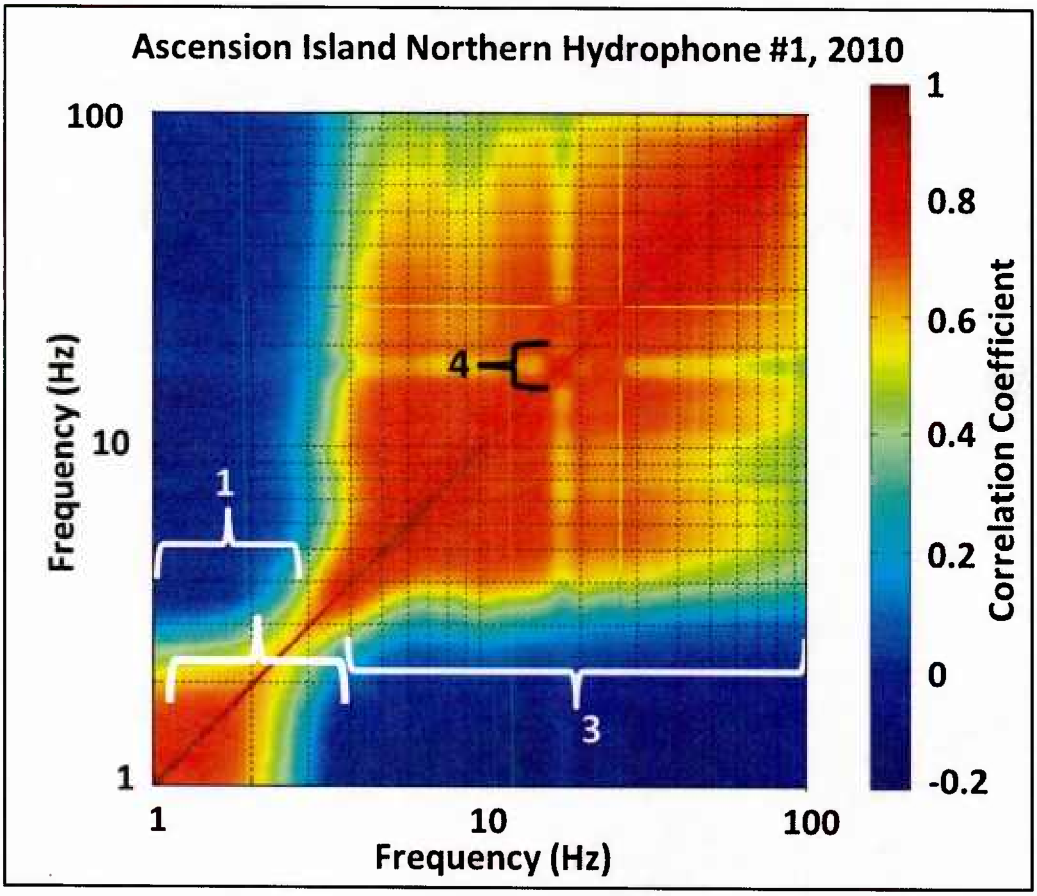


Figure 7. In the Atlantic Ocean, correlation plots reveal the presence of surface wave, seismic exploration, and whale noise. (1. Nonlinear Surface Wave Interactions; 3. Seismic Exploration; 4. Whales)

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